2.5 Case 1 - Protection of the RAS in the 1610.6-1613.8 MHz Band from In-Band MSS Uplink Transmissions (DG2A Report §5.1)

There are a number of techniques available to prevent unacceptable interference from MSS/RDSS systems into radio astronomy. With respect to the MSS/RDSS 1610-1626.5 MHz Earth-to-space transmissions, mobile terminals can be prohibited from transmitting in the 1610.6-1613.8 MHz RAS band when in the vicinity of radio astronomy sites during times of observation. It should be noted that MSS/RDSS terminals onboard aircraft could cause interference to radio astronomy sites at distances much greater than those associated with land-based terminals.

IWG 2 considered two different ways of implementing this approach--viz., protection zones of fixed size around each RA observatory and beacon-actuated protection zones. In either case, the MES would switch to a frequency outside the RAS band when used within the protection zone during times of observation.

2.5.1 Fixed protection zones for in-band MSS transmissions (DG2A Report §5.1.1)

Two calculations using different propagation models were performed to determine the approximate size of the exclusion zone surrounding a RA site to protect it from in-band MES transmissions. One calculation used the "Okumura" model and assumed antenna heights of 30 m and 1.5 m as representative of a radio telescope and a vehicle-mounted antenna, respectively. Taking -238 dB(W/m^{2}Hz) as the threshold of unacceptable interference at non-VLBA sites, and -200 dB(w/m^{2}Hz) for VLBA sites, the distances from the site beyond which an MES transmitter with a typical spectral e.i.r.p. density of -55 dBW/Hz could safely operate were respectively 170 km and 50 km for the two types of sites.

The other calculation used the "Longly-Rice" model for propagation over irregular terrain applied to actual terrain contours at four RA sites. As expected, the safe operating distance for a MES terminal varied widely with azimuth from the RA site, but for some azimuths the distances exceeded those calculated using the Okumura model.

It was concluded that fixed, circular protection zones with radii of 160 km and 50 km would, in general, provide adequate protection at non-VLBA and VLBA sites, respectively.

This conclusion applies only to MES used at ground level. Protection zones for MES on aircraft would have to be based on line-of-sight distances. It was noted that, for an aircraft flying at h meters above the earth, the approximate distance to the horizon is $\sqrt{(2h)}$ km. Beyond-the-horizon propagation by tropospheric scatter will increase the distance required for protection but, to a first approximation, the horizon distance may be taken as the radius of the exclusion zone for aircraft-borne MES.

2.5.2 Beacon-actuated protection zones (DG2A Report §5.1.3)

As a alternative to protection zones of fixed radii, a beacon-actuated protection system offers a method of dynamically protecting (in real time) electromagnetic sensitive locations, such as radio astronomy sites, from in-band MSS mobile terminal (MES) uplink transmissions. Since it is not feasible to restrict the location of the MES and since RAS sites do not make observations in the 1610.6-1613.8 MHz band all the time, a beacon protection system appears to offer significant advantages over other potential RAS sharing solutions.

To implement such a system, one or more omnidirectional radio beacons could be placed near each radio astronomy site that will be conducting observations in the 1610.6-1613.8 MHz band. These beacons would only transmit a signal when such observations were in progress. The number of beacons needed at each site would depend on the location of the site and surrounding conditions. Some RAS sites could be equipped with just one beacon, while other sites might need two or more beacons in order to ensure that local conditions were not masking potential interference into the RAS antenna.

When first requesting a channel assignment from the MSS Control Center on the control channel (which is not in the shared and protected band), the MSS Control Center would determine whether there are any radio emission restrictions associated with RAS observations in that area. If not, the MES would be assigned a communication channel without any restriction on the use of frequencies. If restrictions are in effect in the area of the MES, and the MES receives a beacon signal, the MSS control center would assign the MES a communications channel outside the shared, protected band. Absent receipt of such a signal, MES channel assignment would again be made without-restriction. For example, if the mobile unit is shielded from the beacon by propagation obstructions (e.g., intervening terrain), then it would not receive a beacon signal and transmissions would continue without restriction. In that event, the mobile unit would be able to communicate with the satellite on any channel, and the radio astronomy site would not be affected.

On the other hand, if the mobile unit receives a beacon signal, transmissions over certain frequencies may be automatically inhibited or the system control facility may decide when transmissions would be acceptable. Alternatively, the mobile unit could be equipped to measure the power of the beacon signal and compare it with an appropriate threshold level. If the measured power level is above the appropriate threshold, the mobile unit would be automatically inhibited, or could be switched to a different frequency to prevent interference. Depending on the characteristics of the satellite system, a "beacon received" message could be incorporated in the header message of a mobile unit, and thereby notify the control center that a particular terminal is subject to emission control.

A beacon protection system may offer several potential advantages over other proposed sharing techniques. It may provide for adequate protection to RAS sites during periods of observations (i.e., when the beacons are turned on), while affording the flexibility of MSS terminals to operate virtually without restriction during other periods of time (i.e., when the beacons are turned off). A beacon system may also minimize the geographic protection areas around RAS sites during periods of observation by utilizing real RF boundaries in all directions. If an MSS terminal does not receive a beacon signal due to propagation losses or other real-world effects, then it will be able to uplink in any frequency channel. On the other hand, the reception of a beacon signal by an MSS terminal would only restrict that terminal's use of certain uplink channels during the period of time that the beacon remained on or the user moved out of range. The signal strength of the beacons could also be adjusted over time to reflect additional or reduced protection requirements as circumstances warranted.

However, there are several theoretical and practical concerns which must be worked out before a beacon system can be implemented as a alternative to protection zones of specified radius around designated radio astronomy observatories.

2.6 Case 2 - Protection of the RAS in the Band 1610.6-1613.8 MHz from MSS/RDSS Uplink Transmissions Outside This Band (DG2A Report §5.1.2)

One of the proposed approaches to protect radio astronomy sites from MES out-of-band emissions (including spurious in this discussion) in the 1610.6-1613.8 MHz band is to employ fixed protection, or exclusion, zones similar to but smaller than those for in-band emissions. These zones would be based upon path loss calculations for each system's relevant operating characteristics, such as frequency plan and out-of-band emission levels.

An alternative approach would be to develop a chart relating separation distance from a radio astronomy site as a function of the MES emission level that would fall in the radio astronomy band. Either approach would only be utilized during periods of observations within the 1610.6-1613.8 MHz radio astronomy band.

A number of calculations were carried out to determine the appropriate size for out-of-band protection zones using two different models to represent over-the-horizon propagation losses. For example, using the parameters of the Globalstar MES, including its out-of-band suppression specifications and the topography surrounding the Green Bank Observatory, these calculations suggested that a single MES user could operate without interference to a non-VLBA site at a distance of more than 10 miles from the site when operating within 4.5 MHz of the edge of the RAS band, and could approach as close as 7 miles when operating at greater frequency separations.

However, this example provides only one approach to determining exclusion zones for an MSS system and is not intended to be a definitive determination of the protection radius. In an actual simulation, the latest available version of the chosen propagation model should be used, along with appropriate parameters (e.g., 100-m elevation for the feed of the Green Bank telescope, 10-percent interference probability level, etc.). Further, in order to take troposcatter propagation appropriately into account, model calculations have to be run well over the radio horizon, out to the 150- to 200-mile range.

2.7 Case 3 - Protection of the RAS in the 1610.6-1613.8 MHz Band from MSS Secondary Downlinks in the Band 1613.8-1626.5 MHz (DG2A Report §5.2.1)

Only one of the current MSS/RDSS applicants has proposed to use the secondary downlink allocation. To protect the RAS from harmful interference below 1613.8 MHz, three measures are proposed.

The principal measure is to restrict downlink frequencies to a band whose lower edge is separated from the upper edge of the RAS band by a 2.2 MHz guard band.

Second, out-of-band emissions will be controlled by filtering on board the satellite and by selectively controlling the number of downlink channels near the bottom of the band during RA observations.

Third, to ensure that the foregoing steps are effective, a comprehensive program of analysis and testing would be undertaken with the cooperation of the RA community.

2.8 Case 4 - Protection of RAS Observations in the Band 4990-5000 MHz from Spurious Emissions by MSS/RDSS Downlink Transmissions in the 2483.5-2500 MHz Band (DG2A Report §5.2.2)

The protection requirement in this case is that the spectral power flux density (spfd) level not exceed -241 dB(W/m^{2}Hz). At the e.i.r.p. levels typical of proposed MSS/RDSS satellites, this implies that second harmonic levels must be down at least 63 dB from in-band levels. The amount of filtering required to achieve this level of second harmonic suppression may be different for different systems depending on their operating level. However, it is believed that the desired level of rejection should be obtainable by proper S-band amplifier device selection and operating conditions plus post-amplifier filtering.

3. SHARING BETWEEN THE MSS/RDSS AND THE AERONAUTICAL RADIONAVIGATION SERVICE (ARNS) AND RADIONAVIGATION-SATELLITE SERVICE (RNSS)

3.1 Relevant ARNS and RNSS Frequency Allocations and Interference Cases Considered

The frequency allocations and interference cases to be considered in this section are those listed in Table 1-1 for interference cases 5, 5R, 6, 7, and 8. The characteristics of the systems that use these allocations will be summarized in §3.2 and their interference protection requirements in §3.3.

IWG 2's assessment and analyses of each interference case and of possible approaches to solution are summarized for the five interference cases of interest in §§3.4 through 3.8 respectively.

3.2 Description of the Relevant ARNS and RNSS Systems (DG2B Report §§1.1, 1.2, 1.3, 1.5)

The GPS and GLONASS systems operate under the radionavigation-satellite (space-to-Earth) service allocation in the 1559-1610 MHz band; the GLONASS system also operates in the aeronautical radionavigation service allocation under RR 732. Significant development of both GPS and GLONASS started in the 1970s. The 1979 WARC allocated spectrum for GPS in response to a U.S. proposal. Initial satellites were launched in 1978 (GPS) and 1982 (GLONASS) for experimentation. While neither system has been declared operational, there are 4 block I (developmental), 9 block II, and 9 block IIA GPS satellites in operation. GLONASS has 15 satellites in operation at this time. Each system will have up to 24 satellites in operation at any given time when the systems are fully operational (1994 for GPS, 1995 for GLONASS).

GPS is a space-based positioning, velocity, and time system whose space segment, when fully operational, will be composed of 21 satellites (plus 3 operational spares) in six orbital planes. The satellites will operate in circular 20,200 km (10,900 nm) orbits at an inclination angle of 55° and with a 12-hour period. Each satellite will transmit on two right-hand circularly polarized frequencies L1 (1575.42 ± 1.023 MHz for C/A code) and L2 (1227.60 MHz). L1 will carry a precise (p) signal (provides the Precise Positioning Service (PPS) of ±10.23 MHz which is not available for public use) and a coarse/acquisition (C/A) signal which is used for the Standard Positioning Service (SPS). L2 will carry only a P signal of ±10.23 MHz. Superimposed on these signals will be navigation and system data including satellite ephemeris, atmospheric propagation correction data, and satellite clock bias information. The minimum signal level specified into a 3 dB linearly polarized user receiver antenna located near the ground with a 5° elevation is -160 dBW for SPS and -163 dBW for PPS.

The GLONASS satellite subsystem will include 24 satellites evenly distributed in three orbit planes, eight satellites each plane. Orbit parameters include an altitude of 19,100 km with a period of 11 hours and 15 minutes. The planned rate of replenishment launch is one launch per 7 months of three satellites. The GLONASS functions are similar to GPS except that GPS uses one frequency for all satellites and GLONASS uses 24 frequencies (1602.5625 MHz for the first frequency with each center frequency 0.5625 MHz spacing above for L1). Each satellite has a bandwidth of ±0.511 MHz for C/A signal and ±5.11 MHz for precision signal which is not available for public use. The minimum signal level specified into a 3 dB linearly polarized user receiver antenna located near the ground with a 5° elevation angle is -161 dBW for SPS.

The user segment will consist of antennas and receiver-processors that can receive both GPS and GLONASS signals to provide positioning, velocity, and precise timing to the user. The GPS/GLONASS receiver automatically selects appropriate signals from four of the satellites best in view based on optimum satellite-to-user geometry. It then solves time-of-arrival difference quantities to obtain distance between user and satellites. This information establishes the user position with respect to the satellite system. A time correction factor then relates the satellite system to earth coordinates. The user equipment measures four independent pseudo-ranges and range rates and translates these to three-dimensional position, velocity, and system time.

Further details of the GPS/GLONASS system, including a description of its control segment and planned future changes, are given in the DG2B Report, §§1.2 and 1.5.

The combined GPS and GLONASS systems are part of the Global Navigation Satellite System (GNSS) which the aviation user community seeks to use for en route, oceanic, terminal, and non-precision approach navigation with an accuracy of 100 m. The aviation community envisions that the GNSS will provide the sole means of aeronautical navigation from gate to gate. Further details on the planned operational applications of the GNSS are given in the DG2B Report, §1.3.

The precision, or P-code, signal mentioned in describing the GLONASS space segment is a feature of the "GLONASS-M" system, which the Russian administration has described in advance publication information recently submitted to the IFRB for subsequent international coordination under the procedures of RR Article 14. The GLONASS-M P-code modulation would increase the bandwidth of each GLONASS signal to ±5.11 MHz, extend the upper range of the GLONASS transmissions to 1620.6 MHz, and increase interference both to Radio Astronomy (see §2.3 of this report) and to MSS/RDSS systems.

Approximately 40 countries, including the U.S., have submitted comments/objections to the IFRB in response to the advance publication of GLONASS-M. In view of this and the fact that the P-code signal from GLONASS-M is not envisioned by the aviation community to be part of the GNSS, IWG 2 agreed that it would not need to consider approaches for protecting GLONASS-M against interference from MSS/RDSS uplinks.

3.3 Existing Regulatory Protection for GPS/GLONASS and Protection Sought by the Aviation Community (DG2B Report §§1.4, 1.5, 3)

MSS/RDSS and GLONASS operations in adjacent bands are mutually protected by RR 343, which requires that frequency assignments in both services be sufficiently removed from the common band edge (here, 1610 MHz) to prevent harmful levels of adjacent band interference.

MSS/RDSS and GLONASS operations within the 1610-1626.5 MHz band are governed by RR 731E and 731F. Footnote 731E to the allocation table provides that MSS/RDSS systems are subject to coordination under Resolution 46 (WARC-92), that the MES of such systems shall not radiate an e.i.r.p. density greater than -15 dB(W/4kHz) in the part of the band used by systems such as GLONASS operating in the ARNS under RR 732 or greater than -3 dB(W/4kHz) in the balance of the band unless agreed by affected administrations. Finally, RR 731E states that MSS stations shall not cause harmful interference or claim protection from stations operating under RR 732.

IWG 2 was not able to agree on an interpretation of RR 731E in connection with the requirement to protect GLONASS from harmful interference. Insofar as the protection of a radionavigation service is concerned, "harmful interference" is defined in RR 169 as "interference which endangers the functioning of a radionavigation service or other safety service . . ." There were two difficulties here.

The first is whether operating at or below the e.i.r.p. limits specified in RR 731E satisfied the obligation of MSS uplinks to protect GLONASS from harmful interference. The second is to identify what level is harmful to GLONASS. That level obviously depends on the design characteristics and interference susceptibility of the GLONASS receivers. ARINC Characteristic 743A (March 1992) did not take into account the possibility of operating cochannel with the MSS and can be updated to achieve greater levels of interference immunity.

The GPS/GLONASS receiver specifications are described further in connection with the analysis of sharing feasibility described below for interference case 5.

3.4 Case 5 - Protection of the ARNS in the 1610-1626.5 MHz Band from MSS/RDSS Uplinks in This Band (DG2B Report §§2.1, 3)

IWG 2 reviewed a number of measurements and analyses to determine the general sensitivity of GPS/GLONASS receivers to interference, the maximum interfering e.i.r.p. that such receivers could allow under current specifications, and the level of interference that typical mobile earth station (MES) transmitters would produce at a GPS/GLONASS receiver. These investigations are described in §§3.4.1 through 3.4.4. §3.4.5 then summarizes the conclusions to be drawn from the analyses regarding the feasibility of sharing for interference case 5. §§3.4.6 through 3.4.9 describe a number of approaches to improve sharing.

3.4.1 GPS/GLONASS interference susceptibility measurements (DG2B Report §2.1.1)

Comsat Labs and 3S-Navigation Inc. each recently conducted measurements on both Russian and prototype U.S. GPS/GLONASS aeronautical navigation receivers to investigate their susceptibility to in-band interference from uplink transmission of hand-held MSS terminals. Using "live" signals from GLONASS satellites, the variation of the receiver carrier-to-thermal noise density, C/N_0 vs time and the dependence of the ratio of carrier-to-(noise + interference) density $C/(N_0+I_0)$ on interference density I_0. Both CW and a simulated 600 kHz spread-spectrum signal (300 bps, random modulated (I/O) bit stream) were injected cochannel with the GLONASS signal.

The resultant plot of $C/(N_0+I_0)$ vs I_0/N_0 indicated that the former decreases with increasing interference at about a dB-for-dB rate. However, the effect of interference was somewhat less than that of an equivalent amount of thermal noise. Moreover, none of the navigation outputs from the receiver was affected by the injected interference until the receiver lost track or synchronization at a value of $C/(N_0+I_0)$ below about 28 to 30 dB-Hz.

3.4.2 Interference analysis based on established and proposed GNSS characteristics (DG2B Report §2.1.2)

ARINC provided an analysis to determine the maximum interference e.i.r.p. from an uplink mobile earth station (MES) transmitter that a GNSS receiver could accept assuming that it embodies current specifications for in-band and out-of-band interference rejection (16 dB interference-to-carrier ratio). If was also assumed that the minimum carrier power at the receiver input would have to be -137 dBm.

The results of the ARINC analysis were that the e.i.r.p. density of an MES transmitter should not exceed -78.5 dBW/MHz when the MES is 100 m from the aircraft (a worst case corresponding the GNSS use during landing), nor -30.4 dBW/MHz when it is 12,000 m away (corresponding to aircraft cruising altitude of about 10,000 m).

3.4.3 Analyses of potential levels of interference produced by a "typical" MES (DG2B Report §2.1.3)

Two analyses were undertaken to determine what levels of interference would be produced at a GPS/GLONASS receiver by a CDMA MES hand-held terminal assumed to have an e.i.r.p. density of -25 dBW/4kHz. This level is 10 dB below the -15 dBW/4kHz limit specified in RR 731E but is considered representative of the e.i.r.p.s envisioned by MSS applicants using CDMA with channel bandwidths wider than 1 MHz.

The first analysis assumed that the GPS/GLONASS receiver was being used for en route navigation on an aircraft at an altitude of 10,000 m. Link budgets for a single MES interferer were developed for the wanted and interfering signal paths under two conditions: one with the MES on the ground directly below the aircraft; the other with the aircraft at a 45° elevation angle when viewed from the MES.

The results of the calculation showed that the $C/(N_0+I_0)$ would be greater than 30 dB-Hz in both cases, corresponding to an $E_b/(N_0+I_0)$ greater than 13 dB and a bit error rate of less than 10^{-6} for uncoded GLONASS transmissions. It was estimated that within the 120 square mile area for which the elevation angle was greater than 45°, there would on average be only one user about 20 percent of the time.

The conclusion was that CDMA MES users would not interfere with en route GLONASS navigation at altitudes above 10,000 m. However, aviation interests in IWG 2 stated that this analysis, based on a U.S.-wide average user MES density, was inadequate to demonstrate interference compatibility at a 95 percent confidence level, a minimum for aviation safety services.

The second analysis assumed a more general scenario for en route navigation which made no specific assumption about aircraft altitude. Instead, it calculated the required separation between the MES and the aircraft to ensure a maximum interference level of -190 dBW/Hz at the GLONASS receiver, assuming free space propagation between isotropic (unity gain) antennas. Separation ranges were calculated for each of the CDMA MSS/RDSS applicants, assuming an e.i.r.p. density obtained by dividing the applicant's e.i.r.p. by the corresponding signal bandwidth. The resultant separation distances ranged from 12.3 km to 83.2 km.

3.4.4 Analysis of the availability of GNSS satellites (DG2B Report §2.1.3.1.4)

Computer simulations were performed to examine the availability of the GNSS satellite constellation based on the orbits and operating status of the GPS and GLONASS satellites. The number of satellites visible at an elevation angle of at least 5° at a CONUS mid-latitude site was noted for 5-minute internals over a 51-day period, assuming that the GPS constellation included 22 of the available 24-satellite maximum and that the GLONASS constellation was truncated to include only 12 of the 14 satellites with center frequencies below 1610 MHz.

The results of the simulation indicated that a minimum of five satellites were always visible and that this minimum occurred for a total of only 14 minutes out of the simulated 51-day period. Since only four GNSS satellites are required for navigation, and a fifth satellite to ensure system integrity, it appeared that GLONASS satellites operating above 1610 MHz might not be required either for navigation or terminal approach.

3.4.5 Conclusions regarding the feasibility of frequency sharing in interference case 5 (DG2B Report §3)

Although the calculations described in §3.4.3 above indicated that GLONASS receivers on aircraft at slant ranges of 12,000 m from an MES might be protected, it is clear that based on current technology, MSS systems cannot meet the MES e.i.r.p. density levels (e.g., no more than -78 dBW/MHz for cochannel operation) specified by the aviation community for the protection of aeronautical radionavigation using GLONASS at spacings as small as 100 m.

Based on the analyses reported in the preceding subsections and on the respective technical and operational requirements of the aviation community and MSS operators, it appears that the prospects for compatible cochannel operations in the 1610-1616 MHz band occupied by GLONASS are limited.

Nonetheless, IWG 2 has been able to identify several potential actions that may be used to improve the sharing prospects. These are described in §§3.4.6 and 3.4.7 below.

3.4.6 Possible GLONASS actions to improve the sharing environment (DG2B Report §3.1)

3.4.6.1 Frequency re-use on antipodal GLONASS satellites (DG2B Report §3.1.1)

Unlike GPS, which uses one universal carrier frequency with different coding for each satellite, each GLONASS satellite utilizes a separate, individual downlink transmit carrier frequency. With 24 satellites in the full GLONASS constellation, there are planned to be 24 discrete frequencies in use simultaneously. However, in the satellites currently under construction for GLONASS replenishment, the satellite downlink frequency assignments are programmed by telecommand from the ground control station. Thus, it is assumed that each of the new GLONASS-M satellites has the capability of operating on any of the 24 frequencies between 1602 and 1615.5 MHz.

Because of this frequency agility, it may be possible that some of the satellites, while on opposite sides of the earth, could use the same frequencies without causing self-interference. By reusing frequencies on antipodal satellites, the 24 GLONASS satellites could operate entirely on the

12 frequencies below 1610 MHz. This would result in each orbital plane of 8 satellites occupying only 4 carrier frequencies.

This reconfiguration of the GLONASS frequency plan would have many benefits.

- It avoids all in-band mutual interference with MSS uplinks
- With appropriate filtering of the GLONASS transmitter, it avoids interference to the RAS in the band 1610.6-1613.8 MHz.
- It would benefit the aviation and INMARSAT communities by eliminating stringent filtering requirements in the SATCOM terminal diplexer now required to protect GLONASS receivers on the same aircraft.

IWG 2's analysis of the impact of the suggested reconfiguration on the GLONASS system is that it would be acceptably small. The inherent frequency agility of the newer GLONASS satellites makes it possible to operate on 12 frequencies rather than 24 without affecting the satellite design. And, although it would be necessary to replace older Russian-built receivers, the required changes to the receiver circuitry are straightforward, as explained in detail in DG2B Report §3.1.1.

Finally, the aeronautical community has indicated that they would have no fundamental objection to the reconfiguration.

3.4.6.2 GLONASS frequency shifting plan (DG2B Report §3.1.2)

A more radical approach to removing the GLONASS frequencies from the 1610-1626.5 MHz band is to shift all 24 GLONASS frequencies by about 11.5 MHz to lie below 1610 MHz but still above the adjacent GPS frequency assignments. This would offer the same benefits as the reuse of GLONASS frequencies on antipodal satellites, but could require system redesign.

3.4.6.3 Enhanced receiver standards (DG2B Report §3.1.3)

With the advance notice the MSS systems will be deploying satellites in the 1610-1616 MHz band by 1997, the aviation community, including the GLONASS and GPS and aeronautical receiver manufacturers, should be encouraged to modify GLONASS receiver performance standards in order to reduce GLONASS's vulnerability to in-band interference from MSS. It is noted that the AEEC has recently proposed more stringent standards (from 13 to 21 dB for interference rejection).

It is also noted that this approach is unlikely by itself to provide enough additional rejection to enable MSS systems to protect GLONASS to the degree desired by aviation. Nevertheless, it may be helpful if employed in conjunction with other interference mitigation techniques.

3.4.6.4 Revision of proposed aviation reliance on GLONASS as a component of the GNSS (DG2B Report §3.1.4)

The aviation community has stated that it must use both GPS and GLONASS to provide the necessary integrity and availability it requires for a GNSS on which reliance is placed. IWG 2 suggests that the aviation community consider alternatives to the sole means reliance on GLONASS. Such alternatives include additional GPS satellites, use of navigational packages on geostationary satellites to validate and supplement GPS, and other means of augmenting GPS.

If MSS is to operate on a cochannel basis with GLONASS, the aviation community must diminish its anticipated reliance on this system as a part of the GNSS.

3.4.7 Other approaches

IWG 2 examined the following three additional approaches to reducing the sharing problems associated with interference case 5, but none were considered to be nearly so effective or easy to implement as the GLONASS actions described in the previous section.

3.4.7.1 Maximum permissible e.i.r.p. density from hand-held MES terminals (DG2B Report §3.2)

The objective of defining a maximum permissible e.i.r.p. or e.i.r.p. density for MSS terminals operating cochannel with GLONASS is to ensure that the GLONASS user will have sufficient margin to operate successfully. However, there is a very large disparity between the value in RR 731E (-15 dBW/4kHz) and the values proposed by the aviation community to protect GLONASS receivers within as little as 100 m of an MES terminal. As a result, specification of an uplink e.i.r.p. limit will not resolve the sharing issue.

3.4.7.2 Protection zones (DG2B Report §3.3)

Another approach examined by IWG 2 was the concept of exclusion or protection zones around critical GLONASS operational areas such as the final approach paths into airports and en route navigation paths. However, given the protection ranges calculated in §3.4.3 above, fixed protection zones would exclude MES from nearly all of CONUS.

A beacon-actuated protection zone would somewhat reduce the size of the zone along en route paths, but is considered impractical due to the high cost of beacon installation and maintenance. On balance, the protection zone concept appears to be both difficult and expensive.

3.4.7.3 Repositioning the MES user frequency (DG2B Report §3.4)

Another possible approach to protecting GLONASS would be to utilize an avoidance mechanism under the control of the MSS system operator. This mechanism would prevent MESs from transmitting on specific GLONASS frequencies in the 1610-1616 MHz band. However, the approach requires accurate information on the position of the MES before assigning it to transmit on a channel in the 1610-1616 MHz band.

A description of how this approach might be implemented is given in DG2B Report §3.4. While acknowledging that the approach is complicated, IWG 2 believes that it warrants further study.

3.5 Case 5R - Protection of MSS/RDSS Systems from GLONASS (Including GLONASS-M) in the 1610-1621 MHz Band (DG2B Report §2.2)

The satellites of the GLONASS system currently transmit at frequencies on which MSS satellites would like to receive uplink transmissions from MESs. Thus, there are space-to-space paths on which the GLONASS system can interfere with MSS uplinks. The problem is exacerbated by the fact that there is no regulatory limit on the PFD used by GLONASS and the possibility that the advance-published e.i.r.p. levels for GLONASS may understate the actual power levels.

Because not all system applicants plan to use low-earth-orbit (LEO) satellites, IWG 2 analyzed two types of interference geometries: uplinks to geostationary MSS satellites and uplinks to non-geostationary MSS satellites. In both cases, the advance-published GLONASS e.i.r.p.s were assumed; therefore, the results may be overoptimistic.

In the geostationary case, the only MSS uplink channels that would suffer unacceptable interference were CDMA channels operating below 1616 MHz.

In the case of LEO MSS systems, no examples of unacceptable interference were found.

3.6 Case 6 - Protection of GLONASS in the 1610-1616 MHz Band from Secondary MSS Downlinks in the 1613.8-1626.5 MHz Band (DG2B Report §2.3)

Motorola's IRIDIUM system is the only MSS applicant planning to use the secondary MSS downlink allocation at 1613.8-1626.5 MHz. The GLONASS system will be protected against harmful interference from IRIDIUM downlinks by five mechanisms: 1) band separation; 2) controlled out-of-band emissions; 3) a guard band in some circumstances; 4) a comprehensive analysis and testing program; and 5) international coordinations.

Each of these mechanisms was briefly elaborated in §2.5.3 of this report in connection with the protection of the RAS under interference case 3.

3.7 Case 7 - Protection of ARNS and RNSS below 1610 MHz from Out-of-Band Emissions by MSS/RDSS Uplinks in the 1610-1626.5 MHz Band (DG2B Report §2.5)

Two types of scenarios have to be considered under this interference case: 1) interference to airborne radionavigation in the vicinity of final approach to an airport; and 2) interference to ground-based public safety users of GNSS signals such as the GPS standard positioning service (SPS) centered at 1575.42 MHz.

Before summarizing IWG 2's analyses of these two cases, it should be recalled from the description of the GPS space segment in §3.2 above that the GPS satellites orbit at an altitude of 20,168 km and their signals at the earth's surface are -160 dBW from a 3 dB linearly polarized antenna. Hence, they are vulnerable to out-of-band emissions near 1575 MHz from MES located in close proximity to a GPS navigation receiver.

3.7.1 Interference to airborne GPS navigation on final approach paths (DG2B Report §§2.5.2, 2.5.4)

Interference can influence GPS in two ways on final approach: 1) disrupting reception at the ground-based differential GPS receiver site, and 2) disrupting GPS reception aboard the aircraft. The use of differential GPS is necessary to achieve position determination with the required accuracy of a few meters.

For the former type of interference, physical separation of the MES uplink terminal from the differential GPS receiver and control of out-of-band emissions from the MES are the principal means of control. A calculation of required separation based on the out-of-band filtering characteristics of the INMARSAT-C MES terminal is presented in DG2B Report §2.5.4. It suggests that separations of tens of meters will suffice.

For interference to the aircraft GPS receiver, the geometry of the interference path is different since the aircraft is normally at a higher altitude than the MES terminal. As a result, there will be some shielding from the aircraft wings and body.

3.7.2 Interference to ground-based public safety users (DG2B Report §2.5.3)

Here the GPS navigation receivers are mounted on vehicles such as police cars, fire trucks, and ambulances. As a result, the MES transmitter and the GPS receiver are likely to be at the same height and only a few meters apart (e.g., the width of a highway lane). However, the relative vehicle motion should bring the public safety vehicle within interference range only for a short time. This relative motion allows some improved rejection through navigation solution averaging in the GPS receiver. Suppression of out-of-band emissions at the MES transmitter is also important.

3.8 Case 8 - Protection of the ARNS and RNSS below 1610 MHz from Out-of-Band Emissions by Secondary Downlinks in the 1613.8-1626.5 MHz Band (DG2B Report §2.5)

IWG 2 concluded that interference from L-band MSS secondary downlinks to GPS reception will be negligible because of the low level of MSS satellite signals (-139 dBW/m^2) and the large frequency separation involved.

4. SHARING BETWEEN THE MSS/RDSS AND SERVICES OTHER THAN THE RAS AND ARNS/RNSS

4.1 Relevant Frequency Allocations and Interference Cases To Be Considered

The radiocommunication services and frequency allocations which may cause interference to, or be subject to interference from, MSS/RDSS systems are those listed in Table 1-1 for interference cases 9 through 16 and 9R through 15R. The characteristics of the systems that use each allocation will be included in the discussion of the sharing problems and sharing approaches for the corresponding interference case.

4.2 Cases 9 and 9R - Sharing Between the Fixed Service (FS) Operating under RR 730 and MSS/RDSS Uplinks in the 1610-1626.5 MHz Band (DG2C Report §§3.1, 3.2, 5.1, 5.2.1.4)

The FS has a primary allocation that includes the 1610-1626.5 MHz band only in the 20 pre-1990 countries cited in RR 730 (MOD WARC-92). These include 11 in Europe (FR Germany, Austria, Bulgaria, Spain, France, Hungary, Poland, the German DR, Romania, Czechoslovakia, and the USSR), 7 in Africa (Cameroon, Guinea, Libya, Mali, Nigeria, Senegal, and Tanzania), and 2 in Asia (Indonesia and Mongolia). Thus, this sharing case does not pertain to the U.S. or other Region 2 countries.

A search of the ITU International Frequency List revealed only one FS system registered in the 1616-1626.5 MHz band. IWG 2 was not able to obtain more complete information about other non-military FS systems that might be operating under RR 730. However, IWG 2 was informed that seven of the eight NATO European countries using the 1610-1626.5 MHz band for military communications under RR 730 have recently indicated that they will withdraw from use of this band before MSS operations commence. The U.S. Army in Europe intends to vacate the band by 1 October 1993.

In RR 730 countries where FS systems do operate, MSS/RDSS system operators should be able to avoid L-band interference from their uplinks by employing protection zones around existing FS locations. In addition, some MSS applicants will be able to avoid interference by using narrow band transmissions and alternative frequencies in coverage areas where other services are operating in foreign countries.

MSS operators should be able to coordinate MSS uplinks with foreign administrations by agreeing to accept a protection zone sufficient to protect an operating point-to-point FS link. MSS receivers should be able to obtain a position signal from the satellite to avoid transmissions in these protection zones. If the MSS transmitter is within the protection zone, potential interference could be avoided by either ceasing transmission or by operating on a frequency not used by the FS operator.

4.3 Cases 10 and 10R - Sharing Between Secondary FS Systems Operating under RR 727 and Secondary MSS Downlinks in the 1613.8-1626.5 MHz Band (DG2C Report §§3.2.2, 5.2.1)

In addition to the 20 countries where the FS has a primary allocation under RR 730, there are 29 countries, mostly in Africa, where it has a secondary allocation under RR 727. However, the

International Frequency List does not identify any such systems, and IWG 2 was unable to obtain information about foreign FS systems that might be operating under RR 727.

If there are RR 727 countries where such systems do exist, proposed MSS systems operating downlinks in the L band should be able to avoid potential mutual interference by using narrow band transmissions and different frequencies in coverage areas. MSS systems can also rely upon the new international notification and coordination procedures of Resolution 46 (WARC-92) and mandated for secondary MSS downlinks by RR 731F (WARC-92) to identify and resolve particular sharing and interference concerns of other administrations.

Coordination with systems operating in the FS could be accomplished by a number of means, depending upon the number of systems in operation, the frequencies they use, and where they are located. For example, in light of the relatively large amount of spectrum in the RR 727 FS allocation (over 100 MHz), it may be possible to move these systems outside the affected band (less than 13 MHz). Interference could also be avoided through frequency agility in the MSS downlink transmissions by selecting frequencies in certain spot beams not expected to interfere with the fixed service system. It may also be possible to avoid specific geographic locations by controlling the downlink spot beam coverage.

4.4 Cases 11 and 11R - Sharing Between the FS or MS and MSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §4.2)

According to the FCC database, there are 737 licensed FS stations operating in the U.S. in the 2483.5-2500 MHz band. In some cases, multiple transmitters may operate under the same link. As of the mid-1980s, the FCC Rules for terrestrial services prohibit any increase in the number of licensed terrestrial transmitters. The most prevalent domestic uses of such stations are for microwave relay systems serving petroleum companies and for broadcast auxiliary links. The key technical parameters of these systems are given in §4.2.1 of the DG2C Report.

Outside the United States, the International Frequency List (IFL) indicates a total of 128 registered FS assignments as of September 1991. It should be noted, however, that the IFL generally does not reflect the full extent of frequency band usage for the FS.

4.4.1 Interference to the FS from MSS downlinks

The power flux density (PFD) generated by MSS/RDSS spacecraft, in excess of levels prescribed by RR 2566, may result in interfering signals at the receiver input of stations in the FS. The likelihood that these interference levels exceed acceptable levels may be different for geostationary and non-geostationary satellite networks. This interference mechanism is system specific (for both FS and MSS) and can best be addressed during coordination. To eliminate the need to coordinate with other administrations, the MSS/RDSS spacecraft transmission should not exceed the international PFD limits.

4.4.2 Interference to MSS downlinks from the FS

No analyses were provided to quantify the sharing constraints needed to prevent interference to mobile earth stations from domestic terrestrial facilities in the 2483.5-2500 MHz band. The practicality of moving these terrestrial facilities in other bands was not assessed.

Based on assignments in the International Frequency List and the coordination distances specified in Resolution 46 for mobile earth stations operating in the 2483.5-2500 MHz band (i.e., 500 km and 1000 km for ground-based and airborne mobile earth stations), coordination will be needed to determine the potential levels of interference from foreign stations operating in the fixed service. For mobile earth station operation in or over the U.S., coordination will be needed with Canada, Mexico, and Russia. For operation of mobile earth stations outside the U.S., operator coordination will be needed with Argentina, Austria, Belgium, Canada, Chile, Peoples Republic of China, Germany, Spain, France, Netherlands, Iran, Kuwait, Mexico, Malta, Czech and Slovak Federal Republics, Russia, Turkey, and Yugoslavia, as well as other administrations that may seek to notify fixed service assignments in the 2483.5-2500 MHz band.

4.5 Cases 12 and 12R - Out-of-Band Interference Between the FS or MS Operating below 2483.5 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §2.6)

IWG 2 obtained the FCC data base listing of the FS and MS stations operating in the U.S. below 2483.5 MHz. It concluded that any out-of-band sharing problems between the MSS and the broadcast auxiliary service below 2483.5 MHz were likely to be sporadic and inconsequential.

4.6 Cases 13 and 13R - Out-of-Band Interference between the FS above 2500 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §4.7)

In the U.S. the FS allocation above 2500 MHz is used for the instructional television fixed service (ITFS) and microwave multipoint distribution service (MMDS). Transmissions in both services are similar to those of broadcast television and employ 6 MHz channels at e.i.r.p.s between 20 and 37 dBW from antennas with narrow horizontal omnidirectional or cardioid patterns. The lowest ITFS/MMDS channel (2500-2506 MHz) is contiguous with the MSS/RDSS downlink band, with cochannel and adjacent channel stations separated by a minimum of 50 miles. Current FCC requirements specify that out-of-band emissions be at least 60 dB below the ITFS/MMDS carrier.

With an e.i.r.p. comparable to an MSS spacecraft, an MDSS transmitter can produce a signal just above 2500 MHz whose PFD at an MES receiver 1 km away is 70 dB higher than the maximum PFD that the MSS spacecraft can produce. It may be concluded that out-of-band interference from MSS downlinks into the FS above 2500 MHz (case 13) is not a problem. On the other hand, interference in the reverse direction will be a serious problem unless MMDS out-of-band emissions from the lower channel are suppressed by much more than the current 60 dB requirement.

IWG 2 concluded that out-of-band emissions from the lowest channel should be limited to -90 dB relative to the carrier at a frequency offset from band edge between 1.25 and 2 MHz, assuming that the channel is operating at 30 dBW e.i.r.p. Adjustments could be made for higher frequency channels and for higher or lower operating e.i.r.p.s. ITFS/MMDS operators acknowledge that they can improve suppression to this level at 2498.75 MHz but that the additional cost per station will be from $10,000 to $30,000 with today's analog NTSC signals.

For tomorrow's stations, which will emit compressed digital video signals, the cost per station likely will be more; the phase delay errors must be corrected far more carefully. Some stations will convert to digital within the next two years and most, we believe, within the decade.

The cost for the improvement of suppression can be reduced appreciably if the target frequency for -90 dB suppression is shifted from 2498.75 MHz to a slightly lower target frequency, such as 2497.7 MHz (attenuation slope not over 22 dB per MHz, as already incorporated in the FCC Rules).

4.7 Cases 14 and 14R - Out-of-Band Interference Between the Broadcasting-Satellite Service (BSS) or Fixed-Satellite Service (FSS) Operating above 2500 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §4.6)

Space-to-Earth links operating in the BSS or FSS in the 2500-2655 MHz band are subject to the PFD limits of RR 2562, and the PFD of emissions falling in the 2483.5-2500 MHz band can be expected to be substantially lower than the RR 2562 levels. Thus, although the PFD allowed under RR 2562 is up to 5 dB greater than the RR 2566 PFD threshold for MSS/RDSS systems in the 2483.5-2500 MHz band, it can be expected that no unacceptable interference will result from this adjacent band sharing. Out-of-band interference from downlinks operating above 2500 MHz into MSS downlinks below 2500 MHz is expected to be at acceptable levels, and vice versa.

4.8 Cases 15 and 15R - Sharing Between the Radiolocation Service (RLS) and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §§4.3, 4.4, and 4.5)

In the U.S., the RLS is allocated in this band for government use only on a non-interfering basis (footnote US 41) and so interference to and from U.S. RLS systems is not an issue.

No quantitative analyses of the potential interference from MSS/RDSS satellites to radiolocation receivers were provided. However, it is possible that the PFD constraints needed to protect the fixed service also will adequately protect stations in the radiolocation service, including stations operating under footnote US 41. Coordination could be required in the event that the RR 2566 PFD thresholds are exceeded.

No analyses were provided to quantify the sharing constraints needed for protection of mobile earth stations from foreign radio location transmitters. However, based on assignments in the International Frequency List and the coordination distances for mobile earth stations operating in the 2483.5-2500 MHz band, operator coordination will be needed to determine the potential levels of interference from foreign stations operating in the radiolocation service and to seek protection from those stations. The 500 km and 1000 km coordination distances in Resolution 46 pertain. For protection of mobile earth station operations in or over the U.S. and abroad, coordination will be needed with Canada and France (St. Pierre & Miquelon).

4.9 Case 16 - Protection of MSS/RDSS Downlinks in the 2483.5-2500 MHz Band from Interference from Industrial, Scientific, and Medical (ISM) Emissions (DG2C Report §4.8)

The 2400-2500 MHz band is allocated internationally by ITU footnote 752 and domestically by Part 18 of the Commission Rules for use by Industrial, Scientific, and Medical (ISM) applications. ISM uses include microwave ovens, door openers, high frequency lighting systems, industrial equipment, and other low-powered devices such as wireless communication devices. It is estimated that there are over 80 million microwave ovens currently in operation in the U.S., with over 200 million microwave ovens worldwide. Industrial equipment, high-efficiency lighting systems, and wireless communications devices (e.g., R-LANs) are also increasing the use of the ISM band in the U.S. and abroad.

IWG 2 reviewed the results of measurements on microwave oven emissions included in NTIA Technical Memorandum 92-154. These measurements showed emissions at 2480 MHz averaging about -50 dBm in a 300 kHz bandwidth at the output of a 2.5 dB receiving antenna located 3 m from the oven. Starting with these data, and assuming free space propagation, IWG 2 calculated that this emission level was equivalent to a PFD of $-141\ \mathrm{dBW/m^2 \cdot 4\ kHz}$ at a distance of 3 km which is comparable to the PFD from an MSS satellite. Even allowing for terrain loss and building blockage (since most microwave ovens operate indoors), the calculations suggested that microwave ovens may cause interference to MES terminals operating in the lower part of the band within 1 km of an operating oven.

The NTIA report also included the results of measurements of composite emissions received at mountain sites overlooking Boulder, CO, with the objective of estimating the equivalent e.r.i.p. of the ISM environment in Boulder. Based on these data, IWG 2 calculated (DG2C Report §4.8.1) that the amount of ambient interference is significantly above the thermal noise floor of a typical MSS receiver in the 2483.5-2500 MHz band, with a consequent reduction in MSS capacity in urban areas.

IWG 2 concluded (DG2C Report §4.8.3) that, in a cumulative environment, there may be a significant ISM interference noise floor in populated areas. Any MSS user terminal operating in such areas may experience varying levels of cumulative interference exceeding the thermal noise of the receiver. IWG 2 notes that a Geostar study conducted in 1983, when there were 10 million microwave ovens compared to 80 million today, produced some data that are different from the NTIA study.

To the extent that there is a problem from ISM interference, a possible solution is dual mode operation using terrestrial cellular systems. This problem is likely to increase as more and more ISM devices enter the marketplace. Also, the types of interference will become more diverse as different types of uses become prevalent.

IWG 2 considered several possible methods of mitigating ISM interference in the band. None of these methods, however, offers a complete solution to the problem.

- Suppression of ISM emissions does not appear to be a likely solution in the short term, given the extensive use of the band for ISM applications. In the long term, the FCC could consider tightening its regulations for occupied bandwidth and leakage of ISM devices.

- The bursty nature of microwave oven emissions offers a potential for pulse blankers to mitigate the effects of interfering signals. Such signal processing, however, has several drawbacks and limitations, including (i) reduced sensitivity of the MSS receivers, (ii) difficulties in processing out the relatively high ISM interference levels, and (iii) the fact that no one signal processing solution can eliminate the various interference sources.

- Increasing the power per channel of the MSS downlink to overcome ISM interfering power would substantially reduce the overall system capacity of systems sharing on an interference basis, and is otherwise limited by the PFD coordination triggers for protecting fixed services in the band.

- MSS systems could decide to avoid those areas with high ambient ISM noise. This might be accomplished by using dual mode user terminals which would operate in the terrestrial cellular mode in urban areas and in the MSS mode in remote unpopulated areas.

5. RECOMMENDED RULES ON INTERSERVICE SHARING

IWG 2 recommends the following rules for the protection of the Radio Astronomy Service in the 1610.6-1613.8 MHz band for inclusion in Part 25 of C.F.R. 47.

(1) Ground-based mobile earth stations will not transmit within the band 1610.6-1613.8 MHz when located within the protection zones defined by the radio observatory coordinates and separation distances specified in Table [25.xxx] during periods of observations in this band as notified to the MSS/RDSS system operator by the Electromagnetic Spectrum Management Unit (ESMU), National Science Foundation, Washington, DC.

For airborne transmitters operating in the 1610.6-1613.8 MHz band, the separation distance shall be the larger of the distance specified in Table [25.xxx] or the distance d(km) as given by the formula:

$$d(km) = 4.1 \sqrt{h}$$

where h is the altitude of the aircraft in meters above ground level.

A beacon-actuated protection zone may be used in lieu of the fixed protection zones defined in Table [25.xxx] if a coordination agreement is reached between an MSS/RDSS system operator and the Electromagnetic Spectrum Management Unit, National Science Foundation, Washington DC, on the specifics of such beacon operations.

Radio Telescope	Latitude Longitude	Distance (km) co-channel
Arecibo, PR	18 20 46 66 45 11	160
Green Bank, WV	38 25 59 79 50 24	160
VLA NRAO, San Agustin, NM	34 04 43 107 37 04	160
Pie Town, NM (VLBA)	38 18 04 108 07 07	50
Los Alamos, NM (VLBA)	35 46 30 106 14 42	50
Kitt Peak, AZ (VLBA)	31 57 22 111 36 42	50
Ft. Davis, TX (VLBA)	30 38 06 103 56 39	50
N. Liberty, IA (VLBA)	41 46 17 91 34 26	50
Brewster, WA (VLBA)	48 07 53 119 40 55	50
Owens Valley, CA	37 13 54 118 16 34	160 50 (VLBA)
St. Croix, VI (VLBA)	17 45 31 64 35 03	50
Mauna Kea, HI (VLBA)	19 48 16 155 27 29	50
Hancock, NH (VLBA)	42 56 01 71 59 12	50
Ohio State, OH	40 15 06 83 02 54	160

Table 25.xxx   Radio Astronomy Protection Zones

In the absence of a coordinated beacon-actuated protection zone, the MSS/RDSS system shall be capable of providing this protection within the first position fix of the mobile terminal prior to transmission or as soon as practicable after entering into a protection zone.

Discussions between MSS/RDSS operators and ESMU shall be undertaken to avoid scheduling radio astronomy observations during peak MSS/RDSS traffic periods to the greatest extent practicable.

(2) The radii of the protection zones identified in subsection (1) shall be reduced upon a showing by an MSS operator to the ESMU and good faith agreement that the operation of a mobile earth station will not cause harmful interference to a radio astronomy observatory during periods of observation.

(3) Additional radio astronomy sites, not located within 100 Miles of the 100 most populous urbanized areas as defined by the United States Census Bureau at the time, may be afforded similar protection one year after notice to the MSS/RDSS system operators and the issue of a public notice by the Commission.

(4) Each MSS/RDSS system applicant shall include in its application a showing that these requirements will be satisfied.

6. OTHER CONCLUSIONS AND RECOMMENDATIONS ON INTERSERVICE SHARING

The conclusions and recommendations of IWG 2 regarding the 24 cases of inter-service interference listed in Table 1-1 are as follows:

6.1 Case 1 - Protection of the Radioastronomy Service (RAS) in the Band 1610.6-1613.8 MHz from In-Band MSS/RDSS Uplink Transmissions

6.1.1 Fixed protection zones (DG2A Report §6.1.1)

IWG 2 recommends: 1) that a protection zone of 100-mile (160 km) radius around the Arecibo, PR, Green Bank, WV, VLA (San Augustin, NM), Owens Valley, CA, and Ohio State University, OH radio astronomy observatories listed in Table 3-1 of the DG2A Report, and any others subsequently added under the provisions described below, will protect them from unacceptable interference from uplink transmissions from mobile earth stations (MES) in the band 1610.6-1613.8 MHz; and 2) that such a protection zone be incorporated in the Commissions' Rules.

IWG 2 also recommends: 1) that a protection zone of 30-mile (50 km) radius around the VLBA observatories listed in Table 3-1 of the DG2A Report, and any others subsequently added under the provisions described below, will protect them from unacceptable interference from uplink transmissions from MES in the band 1610.6-1613.8 MHz; and 2) that such a protection zone be incorporated in the Commission's Rules.

IWG 2 concludes that an RAS observatory may be deleted from the list of protected sites upon publication of an FCC Public Notice, and added to the list of protected sites one year after publication of such a Public Notice, following notification to the Commission of such deletions and/or additions, by the Electromagnetic Spectrum Management Unit (ESMU), National Science Foundation, Washington, DC 20550, except that Radio Astronomy observatories within 100 miles of the 100 most populous urbanized areas as defined by the U.S. Census Bureau at the time shall not be added to the list of observatories that must be protected.

System operators should be required by the Commission's Rules to include in their applications analyses to demonstrate that MESs in their systems located in, or entering into, a protection zone will be detected within the first position fix of the mobile terminal prior to transmission, or as soon as practicable after entering the protection zone, and assigned, or reassigned, a non-interfering communication channel outside the band 1610.6-1613.8 MHz.

The radius of the protection zone around an observatory, perhaps as a function of azimuth, could be reduced (never increased) by coordination with the operator of that observatory, or by the use of a beacon-actuated protection zone as described below.

6.1.2 Beacon-actuated protection zones (DG2A Report §6.1.3)

Beacon-actuated protection zones could provide an acceptable alternative to fixed protection zones for operating MES near RAS observatories. However, the concerns discussed above must be worked out to demonstrate the practical, technical, and economic feasibility of the beacon concept as an alternative to protection zones of specified radius around designated RAS sites. Since implementation of MSS/RDSS systems will undoubtedly take a few years, there will be time to resolve these questions.

In order for this approach to work in practice, there must be close coordination between the MSS system proponent and the RA community. Accordingly, the Commission should adopt a rule which would require any MSS licensee that proposes to rely upon such a beacon approach to coordinate its system design, testing, and operating procedures through the Electromagnetic Spectrum Management Unit (ESMU) of the National Science Foundation, CORF, or other suitable entity designated by the radio astronomy community. The Commission should also require that all parties negotiate suitable agreements in good faith and on a timely basis.

In summary, a beacon-actuated protection zone could be used in lieu of the protection zone of specified radius around an RAS observatory following coordination of the specific beacon system to be employed with the operator of that observatory.

6.2 Case 2 - Protection of the RAS in the Band 1610.6-1613.8 MHz from MSS/RDSS Uplink Transmissions Outside This Band: Fixed Protection Zones (DG2A Report §6.1.2)

IWG 2 concludes that fixed protection zones could be established for out-of-band MSS uplinks in the bands immediately adjacent to the 1610.6-1613.8 MHz band with radii smaller than those for in-band cases given in §5.1 above, and that no protection zones are needed when uplink transmissions are located sufficiently far from the edge of the 1610.6-1613.8 MHz band, provided out-of-band emissions of the MES fall off sufficiently rapidly.

The radii of the fixed protection zones for out-of-band transmissions for non-VLBA sites are determined on the hypothesis that the 100 statute miles radius is a standard for cochannel protection from MES signals with a transmitted e.i.r.p. density of -55 dBW/Hz. We note that with the assumed propagation model, a power of -65 dBW/Hz will produce a flux density at the radioastronomy antenna of -238 dBW/m^{2}Hz. Under some assumptions, this level could cause harmful interference, but the aforementioned standard has been agreed to as a practical criterion.

Figures 6-1 and 6-2 of the DG2A Report show for purposes of illustration the variation from this transmitted power permissible as a function of the radius of the protection zone. Attenuation as a function of distance has been calculated using the Okumura propagation model for open terrain as a working hypothesis. Such use extends the model beyond its normal range of validity; as better models valid over a wider range become available, they should be used.

By way of example, note that if the transmitted power is 10 dB less than the reference value, then the protection zone can be reduced to about 75 miles. A cochannel reduction in power might take place by lowering the transmitter power and an out-of-band reduction because of filtering. Figure 6-3 of the DG2A Report shows the effects of such filtering on out-of-band emissions for three different, but representative, Butterworth filters. The filter and propagation curves can be combined, as in Figure 6-4 of the DG2A Report, to show directly the relation between protection zone radius and frequency offset.

Note that the curves do not go below 1.0 km because the Okumura model is not valid at such short distances. However, it would be desirable to permit operation of MES, even on the grounds of astronomical observatories, if it can be shown that they will not cause interference. It is to be hoped that values for such close ranges will be proposed by one or more of the parties responding to the Commission's NPRM for MSS/RDSS systems above 1.0 GHz, which will be issued in due course.

Figures 6-5 and 6-6 of the DG2A Report are repeats of the first two figures but based on the 30-mile radius protection zone recommended for in-band interference at VLBA observatories.

The attention of the FCC is drawn to the potential impact of providing this level of protection from out-of-band emissions on the various MSS/RDSS sharing approaches under consideration by IWG 1. Likewise, the FCC may wish to consider the impact on system cost of providing the out-of-band signal suppression needed to keep the size of the protection zone acceptably small.

6.3 Case 3 - Protection of the RAS in the Band 1610.6-1613.8 MHz from MSS Secondary Downlink Transmissions in the Band 1613.8-1626.5 MHz (DG2A Report §6.2.1)

IWG 2 recommends that the spectral power flux-density (PFD) reaching the surface of the earth in the band 1610.6-1613.8 MHz from out-of-band emissions from all satellites in an MSS/RDSS system in the band 1613.8-1626.5 MHz not exceed -238 dB(W/m^{2}Hz) during observations at the non-VLBA sites to be protected, and -198 dB(W/m^{2}Hz) during observations at the VLBA sites to be protected.

IWG 2 believes that system operators can comply with this limit through a combination of high-pass filters in the satellite transmitter, and/or employment of a guard band between the lowest satellite channel to be used and the upper edge of the protected band, 1613.8 MHz.

Prospective MSS/RDSS system operators establish that they can meet these requirements through analyses and testing. These analyses and test data should be provided to the ESMU, well prior to launch, for use within the radio astronomy community, pursuant to a confidentiality agreement.

6.4 Case 4 - Protection of the RAS Observations in the Band 4990-5000 MHz from Spurious Emissions by MSS/RDSS Downlink Transmissions in the 2483.5-2500 MHz Band (DG2A Report §6.2.2)

IWG 2 recommends that the spectral power flux-density (PFD) reaching the surface of the earth in the band 4990-5000 MHz from spurious emissions from all satellites in an MSS/RDSS system in the band 2483.5-2500 MHz not exceed -241 dB(W/m^{2}Hz).

IWG 2 believes that system operators can comply with this limit through a combination of suppression of second harmonics in satellite transmitters and filtering of the output.

Prospective MSS/RDSS system operators establish that they can meet these requirements through analyses and testing. These analyses and test data should be provided to the ESMU, well prior to launch, for use within the radio astronomy community, pursuant to a confidentiality agreement.

6.5 Case 5 - Protection of the Aeronautical Radionavigation Service (ARNS) in the 1610-1626.5 MHz Band (and, Specifically, the GLONASS System Operating under RR 732) from MSS/RDSS Uplinks in This Band and Case 5R - Protection of MSS/RDSS Systems from the ARNS (Including Aeronautical Radionavigation Radars Operating in Sweden under RR 731) in the 1610-1626.5 MHz Band

6.5.1 Reconfiguration of GLONASS frequency plan (DG2B Report §4.1)

IWG 2 believes that the best solution to enable both MSS and GLONASS to operate compatibly without operational constraints is to effect a reconfiguration of the GLONASS frequency plan. As discussed in Section 3 of the DG2B Report, IWG 2 believes that this reconfiguration can be achieved without requiring modification of the GLONASS spacecraft design and without compromising the operational objectives for use of GLONASS as stated by the aviation community. In addition, this approach will also resolve much of the current interference from GLONASS experienced by radioastronomy.

To achieve this objective, the FCC, along with other appropriate U.S. government agencies, should initiate discussions with the Russian administration concerning this reconfiguration. Such an approach should also be made an integral part of any U.S.-Russia discussions concerning Article 14 coordination of GLONASS-M.

Absent an agreement on the part of the Russian Administration to shift or fold these frequencies as proposed in Sections 3.1.1 and 3.1.2 of the DG2B Report, less extensive adjustments to the GLONASS frequency plan should be pursued by the United States.

6.5.2 Enhancing the GPS system to reduce need for protection of GLONASS (DG2B Report §4.2)

The aviation community, within this proceeding, has emphasized its desire to use the GNSS as a "sole means" navigation system, for multiple applications. The aviation community should be asked to explore all possible alternatives to provide it the integrity and availability it seeks in the GNSS, including enhancement of the GPS system through the deployment of more GPS satellites, and use of other facilities. If protection of GLONASS to the extent sought by aviation is mutually exclusive with the operation of MSS systems, IWG 2 suggests that the FCC work with the aviation community to identify a means to use GPS with non-GLONASS augmentations to meet aeronautical navigation requirements.

6.5.3 Adoption of e.i.r.p. limits for MSS/RDSS uplinks (DG2B Report §4.3)

IWG 2 recommends that the Commission adopt the uplink e.i.r.p. density limits contained in RR 731E. Adopting these limits is necessary to enable the proposed MSS systems to be brought into use and support an important and beneficial U.S. initiative to provide mobile communications.

However, it is noted that the aviation community believes that adherence to the -15 dBW/4kHz limit will not assure protection to GLONASS for most aeronautical applications. If the Commission were to accept the aviation community's stated requirements for use of GLONASS as a component of a "sole means" GNSS, the co-primary MSS allocations in the 1610-1616 MHz band would be effectively nullified because of the disparity between aviation's protection requirements and practical e.i.r.p. levels needed to support satellite uplinks.

The FCC's adoption of such a rule does not imply protection of the GLONASS system to the extent desired by the aviation community.

6.5.4 Restriction of use of mobile earth stations on aircraft (DG2B Report §4.5)

In order to protect operations of GLONASS receivers and other navigational avionics on-board aircraft, the Commission should adopt a rule which prohibits the operation of mobile earth stations used with geostationary and non-geostationary satellites on civil aircraft, unless the MES has a direct connection to the aircraft Cabin Communication System.

6.5.5 Conclusions for case 5R (DG2C Report §2.4)

IWG 2 concludes that the Swedish radars operating in the ARNS at L band under RR 731, because of their sparse locations and pulsed operation, will not cause harmful interference to MSS operators with well designed receivers, nor will MSS operations interfere with them.

6.6 Case 6 - Protection of GLONASS in the 1610-1616 MHz Band from Secondary MSS Downlinks in the 1613.8-1626.5 MHz Band (DG2B Report §4.4)

IWG 2 finds that allocating the 1613.8-1626.5 MHz band to the MSS in the space-to-Earth direction on a secondary basis is consistent with sharing with GLONASS. In order to facilitate the operation of the secondary downlink in this band in a manner which will not cause harmful interference to GLONASS, space stations which utilize this band for downlink shall not exceed a power flux density of -141.5 dBW/m^2-4kHz in the GLONASS operation band.

6.7 Case 7 - Protection of the ARNS and Radionavigation-Satellite Service (RNSS) below 1610 MHz from Out-of-Band Emissions by MSS/RDSS Uplinks in the 1610-1626.5 MHz Band (DG2B Report §4.6)

IWG 2 recommends that mobile units that operate with mobile-satellite systems utilizing any portion of the 1610-1626.5 MHz band should limit their out-of-band emissions so as not to exceed an e.i.r.p. density of -70 dBW/1MHz averaged over any 20 ms period in any portion of the 1575.42 +/- 1.023 MHz band for broadband noise emission. For any discrete spurious emissions in the same band, i.e., bandwidth less than 600 Hz, the e.i.r.p. should not exceed -80 dBW. IWG 2 was not able to reach a consensus on out-of-band emission limits to protect GLONASS. Such out-of-band limits will be considered following a determination of whether the GLONASS frequency plan can be revised or reconfigured. The aviation community is in agreement that the same MES out-of-band emission limits of -70 dBW/1MHz broadband and -80 dBW narrowband (i.e., bandwidth less than 600 Hz) should also apply to any portion of the GLONASS operation band below 1610 MHz.

6.8 Case 8 - Protection of the ARNS and RNSS below 1610 MHz from Out-of-Band Emissions by Secondary MSS Downlinks in the 1613.8-1626.5 MHz Band

The conclusions for this case are the same as those for Case 6, since it merely represents an extension of Case 6 to the ARNS/RNSS bands below 1610 MHz.

6.9 Cases 9 and 9R - Sharing Between the Fixed Service (FS) Operating under RR 730 and MSS/RDSS Uplinks in the 1610-1626.5 MHz Band (DG2C Report §2.1)

IWG 2 finds that existing services in the band 1610-1626.5 MHz will not cause harmful interference to MSS operations. The IWG 2 further finds that MSS operations will not cause harmful interference to any existing services in this band (other than RAS and ARNS, dealt with elsewhere). Accordingly, no rule changes or modifications are required.

6.10 Cases 10 and 10R - Sharing Between Secondary FS Systems (Operating under RR 727) and Secondary MSS Downlinks in the 1613.8-1626.5 MHz Band

IWG 2 concludes that this sharing situation is not relevant to the United States. The IFL does not identify any secondary FS systems. In addition, IWG 2 was not able to obtain any other data on secondary FS operations in the countries cited in RR 727 to permit this case to be evaluated.

6.11 Cases 11 and 11R - Sharing Between the FS or Mobile Service (MS) and MSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §2.3)

IWG 2 concludes that MSS could cause harmful interference to terrestrial fixed microwave and mobile radio services under some circumstances. IWG 2 expects that these circumstances will be infrequent and subject to coordination for systems operating above the PFD limit (RR 2566). IWG 2 also notes that there is no inherent technical reason why terrestrial fixed services need to operate in the frequency range 500-3000 MHz, whereas there are well known and fundamental reasons why the mobile services, using omnidirectional antennas, need to use these frequencies. Therefore, IWG 2 recommends that the FCC should take all steps necessary to have existing domestic FS systems in the band 2483.5-2500 MHz moved to higher carrier frequencies, i.e., above 3000 MHz. IWG 2 urges the FCC to work with U.S. and foreign administrations and international agencies to achieve the same ends throughout the world.

6.12 Cases 12 and 12R - Out-of-Band Interference Between the FS or MS Operating below 2483.5 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §2.6)

Except as otherwise mentioned, under the broad categories of fixed and mobile services (including the domestic broadcast auxiliary services (BAS)), IWG 2 did not find any systems likely to cause out-of-band interference to the MSS or to be interfered with. Out-of-band emissions from the BAS below 2483.5 MHz and the broadcasting-satellite service above 2500 MHz were deemed to be inconsequential and sporadic problems, and any problems that do arise with the fixed and mobile services should be easy to coordinate.

6.13 Cases 13 and 13R - Out-of-Band Interference Between the FS above 2500 MHz and the MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §2.2)

IWG 2 finds that there will be no interference from MSS into the domestic ITFS/MMDS services, but that out-of-band emissions from the channels just above 2500 MHz in those services will cause harmful interference with MSS mobile terminals at distances up to several kilometers from a ITFS/MMDS transmitter. IWG 2 recommends that the FCC initiate an NPRM to tighten out-of-band emissions to a level of at least 90 dB below the carrier level at an offset between 1.25 MHz and 2.0 MHz below 2500 MHz.

6.14 Cases 14 and 14R - Out-of-Band Interference Between the Broadcasting-Satellite Service (BSS) and Fixed-Satellite Service (FSS) Operating above 2500 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §2.6)

The IWG 2 conclusions for these cases were covered in Sec 6.12 above.

6.15 Cases 15 and 15R - Sharing Between the Radiolocation Service (RLS) and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §2.4)

IWG 2 concludes that the French radars operating in this band, because of their sparse locations and pulsed operation, will not cause harmful interference to MSS operators with well designed receivers, nor will MSS operations interfere with them.

6.16 <u>Case 16 - Protection of MSS/RDSS Downlinks in the 2483.5-2500 MHz Band from Interference from Industrial, Scientific, and Medical (ISM) Emissions (DG2C Report §2.5)</u>

The measurements conducted by NTIA reveal that, in a cumulative environment, there may be a significant ISM interference noise floor in populated areas. An MSS user terminal operating in such areas may experience varying levels of cumulative interference that may exceed the thermal noise level of the receiver. IWG 2 noted that this situation could be acceptable to operators using terrestrial cellular links in metropolitan areas, but may affect MSS operations in this band in other service scenarios. The FCC should take decisive action to tighten the permitted radiation from ISM devices and to restrict the occupied bandwidths. A copy of the IWG 2 report should be associated with ET docket #91-313, which addresses harmonization of Part 18 of the FCC rules with the international standards for ISM equipment.

APPENDIX A to
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